Acoustic Telemetry of Rocky Reef Fish Home Range to Evaluate Marine Protected Area Size

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Abstract
The goal of the study was to describe the area of habitat used, or home range, by adult copper rockfish inside two San Juan County voluntary "no-take" zones. The methodology involved tagging sixteen copper rockfish with acoustic transmitter tags, and tracking them daily for two months. Tracking was accomplished using a boat with a hydrophone receiver and GPS unit or by passive hydrophone arrays linked to a land-based station. Results showed that most copper rockfish stayed inside the MPA, however fish did move outside—indicating potential for adult spillover and thus properly sized MPAs for copper rockfish. These results generally support previous findings by Matthews (1990) of home range size on the order of 30m^2 in Puget Sound on patch reefs with high substrate complexity; however, extension to the San Juans shows that these fish can inhabit larger home ranges when continuous, high substrate complexity, rocky reef habitat is available.

Background
The 2002 Acoustic Telemetry Project for the San Juan County Marine Resource Committee's Bottomfish Recovery Program answers the question "How small is too small?" for the County's voluntary "no-take" marine reserves. This question is answered by tracking 17 acoustically tagged fish initially captured inside Pile Point or Lime Kiln Bottomfish Recovery Zones (**BRZ**s). Thirteen of the tagged individuals were copper rockfish (*Sebastes caurinus*). In addition, two lingcod (*Ophiodon elongatus*) were tracked, as well as a kelp greenling (*Hexagrammos decagrammus*) and a red Irish lord (*Hemilepidotus hemilepidotus*). The tracking took place from August 3, 2002 to December 2, 2002.

The project comprised two parts. First, manual tracking was completed using a boat equipped with a hydrophone and a Global Positioning System (**GPS**) unit to get daily positions of tagged fish. Second, a Radio-Acoustic Positioning Telemetry (**RAPT**) system was used over an eight-day period at Lime Kiln BRZ to continuously calculate positions of tagged fish approximately once per minute.

The results show that most copper rockfish had small home ranges, and furthermore, that the reserves were large enough to encompass these home ranges. Lingcod and kelp greenling displayed home ranges that appeared to be larger than the reserves. Perhaps other fishery management techniques, such as seasonal openings, slot size limits and bag limits are more appropriate for these species. The red Irish lord had a home range similar in size to most copper rockfish. This proves that reserves designed for target species like copper rockfish may have the additional benefit of protecting other species as well.

While most copper rockfish ranged very little, one fish, a 34cm female, showed two substantial movements—one of which was outside the reserve boundary. This adult spillover is proof of increased fishing opportunities outside the boundaries of the reserve. In addition, this shows that given continuous high relief habitat, some individuals may exhibit much more movement than previously thought.

Introduction
Copper rockfish (*S. caurinus*) are an epibenthic, predominantly sedentary species. Generally, *S. caurinus* has been described as a species with little or no adult movement (Hallacher 1977; Barker 1979; Gowen 1983), however juveniles have shown significant movement before maturity (Buckley and Hueckel 1985).

Matthews (1990a) tagged 512 *S. caurinus* in Puget Sound and re-sighted 51.6% of those fish at least once (and some as many as 17 times) over a two-year period. Estimates of home range size (based on these re-sightings) for fish on high relief reefs were within 30m^2 for 72-81% of re-sighted individuals, within 90m^2 for 18-28% of re-sighted individuals, and within 1500m^2 for 1% of re-sighted individuals. On low relief reefs, home range size estimates were much larger: within 90m^2 for 34-40% of re-sighted individuals, within 400m^2 for 30-40% of re-sighted individuals, and within 1500m^2 for 26-30% of re-sighted individuals. High relief reefs were characterized by steep vertical relief up to 5m off the bottom. Low relief reefs were characterized by flat, featureless cobble and rock bottom with a few isolated areas of 1-2m vertical relief. Home range estimates could not be made for the 48.4% of tagged fish that were not re-sighted.

A related study in Puget Sound used acoustic telemetry to examine home ranges and homing routes of *S. caurinus* (Matthews 1990b). Home ranges of *S. caurinus* were determined to be generally within a 5m^2 area on high relief reefs, but approximately 4000m^2 on low relief reefs. This was taken as evidence that fish not re-sighted in the underwater tagging study mentioned above (Matthews 1990a) had not left the reef, but were in fact not sighted due to a relatively large home range. Acoustically tagged fish in this study were tracked for relatively short duration (17-30 days) due to battery life of tags. In addition, this study tracked fish displaced 500m from their capture location, and determined that *S. caurinus* has a homing ability and was able to cease movement upon reaching the reef from which it was captured.

The study presented here extends the previous work on copper rockfish by examining individuals in continuous nearshore rocky reef habitat, rather than the patch reef habitat found south of Admiralty Inlet. The small home ranges found in high relief habitat may have been caused by the lack of high relief habitat pathways around the patch reef. Tracking individuals in the continuous high relief habitat found in the San Juan Archipelago allows examination of movement behavior that is not limited by habitat.

Larson (1980) tagged two species similar to *S. caurinus*, the black-and-yellow rockfish (*Sebastes chrysomelas*) and gopher rockfish (*Sebastes carnatus*) with visual tags. One-hundred-eighty person-hours were spent observing at three tagging locations around the Channel Islands and Santa Barbara, California. Observations of precise locations and behavior were made during the day, dusk and dawn throughout the year following tagging. He found that *S. chrysomelas* and *S. carnatus* displayed territorial behavior and defended a home range. For individuals with stable, well-defined home ranges, the areas of the home ranges were calculated to be approximately 10m^2. The home range size increased with fish size and with depth. No evidence for territoriality in *S. caurinus* has reported (Matthews 1990a).

Black rockfish (*Sebastes melanops*) are a mesopelagic, schooling species. Most *S. melanops* have shown little or no movement in tagging (mark/recapture) studies (Barker 1979; Coombs 1979; Demott 1983; Gowen 1983). However, individual fish in many of these same studies often show substantial movement. Some fish usually have shown movements of greater than 5 km (Coombs 1979; Demott 1983), and maximum observed movements of up to 22 km, 178 km, 320 km, and 619 km have been reported (Gowen 1983; Demott 1983; Barker 1979; Coombs 1979, respectively). A tagging study off the coast of Washington and northern Oregon during 1981-85 found that movements of *S. melanops* were generally less than 10 miles (Culver 1986). *S. melanops* does not appear to possess a homing ability (Coombs 1979).

Another schooling species, similar to *S. melanops*, is the yellowtail rockfish (*Sebastes flavidus*). Carlson (1972) tagged and released 337 *S. flavidus* over 15 months near Juneau, Alaska, and 74 (or 22%) were recaptured at the initial capture site. The fish had been released at multiple locations, as far as 22.5 km away. This established the existence of a home site and a homing ability for *S. flavidus*.

Lingcod (*O. elongatus*) have been shown to move considerable distances. Recent research at Edgecombe Pinnacle off of Sitka, Alaska, has shown two patterns of adult lingcod movement. Some individuals resided in a small home range, while others left a similarly sized area for long periods of time and later returned to the same location (Starr *in press*). A mark-recapture study done with trawl surveys in the Strait of Georgia revealed movements of males and females in excess of 90km and 71km at rates of 500m/day and 1040/day, respectively (Smith 1990), while other studies have shown non-migratory behavior (Mathews and LaRiviere 1987; Matthews 1992). Movements of kelp greenling (*H. decagrammus*) and red Irish lord (*H. hemilepidotus*) have not been studied previously.

This project used two techniques to locate tagged individuals, manual tracking from a boat and continuous tracking using a mobile hydrophone array.

Methods and Materials

Manual tracking

The tagging procedure involves use of a previously developed protocol (Starr 2000) to implant acoustic transmitter tags in copper rockfish (*Sebastes caurinus*). The University of Washington Animal Care Committee has previously approved the procedure (Griffin 2000). In summary, the protocol involves capture of specimens from depths of less than 20m using rod and reel. Barbs were removed from hooks to prevent injury. The latitude and longitude of capture and release (to nearest thousandth minute), date and time of capture and release, length (cm), sex, transmitter number, external tag number, and approximate depth caught were recorded. Fish to be tagged were anesthetized using MS-222, strapped into the surgery station, scales removed in a 1.5cm area 1-2cm anterior of the vent and scrubbed with Betadine. An incision was made where scales were removed and a transmitter tag inserted. At least three monofilament sutures were used to close the incision. Fish were out of the water for 5 to10 minutes (6 minutes on average). Each fish was also tagged with and external t-bar anchor tag (Floy) on the left side just below the third dorsal spine for visual identification. The external tags were the same specifications as those used by Matthews (1990a).

Manual tracking locations were generated using a Sonotronics USR-90 receiver connected to a B&K 8105 omni-directional hydrophone. The fish was assumed to be directly underneath where the signal strength detected by the hydrophone was loudest and near the substrate. Differences in signal strength could be detected when the hydrophone was moved 10-20m, which provided adequate resolution for the purpose of this study. Latitude and longitude was recorded to nearest thousandth of a minute using a Garmin GPS 12 Channel unit. A bottom sounder was used to get the depth at each location of greatest signal strength. Estimated Position Error (**EPE**), weather and tidal state were recorded for each day of location sampling.

Mobile array

Tracking of tagged fish at Lime Kiln was also accomplished using Radio-Acoustic Positioning and Telemetry (**RAPT**) via a three buoy system built by Vemco, Ltd. of Nova Scotia, Canada. This system uses three moored buoys and a base station on land to continuously monitor and locate transmitter tags. The buoys have a hydrophone receiver and a radio antenna. The base station consists of a PC connected to another radio antenna. Once an hour, the buoys each produce a "ping" which is recorded by the other buoys to determine and update buoy array geometry. The base station synchronizes the clocks in each buoy and instructs the buoys to record on a certain frequency for 10 seconds. Then the buoys send recorded data to the base station. The base station PC uses the differences in arrival times of each transmitter tag signal to compute a location for the source of that signal. Then the base station instructs the buoys to record on another frequency, and continues locating signal sources by cycling through every tag channel once every few minutes. In this application, the RAPT was able to locate each tag around twenty times per hour.

Two buoys were attached to mooring lines run from large concrete blocks in about 20m of water. Mooring lines were kept under tension by three 15 foot lengths of ½ inch bungee cord. This minimized shifts in array geometry during tide cycles. The third buoy was attached to a 20-foot-long, 2-inch-diameter steel pole. The pole was anchored in the mid-intertidal to a hinge so the buoy could rise and fall with the tide. With some effort, this array system could be set up in another area.

Results

Manual tracking

Acoustic transmitter tags were internally implanted in thirteen copper rockfish (*Sebastes caurinus*), one lingcod (*Ophiodon elongatus*), one kelp greenling (*Hexagrammos decagrammus*), and one red Irish lord (*Hemilepidotus hemilepidotus*) (Table 1) at two San Juan County Bottomfish Recovery Program voluntary "no-take" Bottomfish Recovery Zones (**BRZ**s) (Figure 1). Seven copper rockfish were tracked at Pile Point BRZ (Figure 2). Six copper rockfish, two lingcod, a kelp greenling and red Irish lord were tracked at Lime Kiln BRZ (Figure 3). Locations of tagged fish were determined daily, unless weather prevented operation of a 18' open boat or the mobile was deployed and collecting data.

Four SCUBA dives were made to look for tagged fish. On September 25, the copper rockfish with external Floy tag number 87 was observed in 11m of water, hovering above a boulder pile and retreating into a void when approached. This is normal behavior for a copper rockfish approached by a diver. On November 30, the copper rockfish with external Floy tag number 95 was sighted at the base of an overhanging 2m high wall in 22m of water. The wound from the tag implant surgery was completely healed and did not show any sign of infection. The fish was behaving normally, hovering near the crevice at the base of the wall.

Fish at Pile Point were located between 38 and 46 times, and fish at Lime Kiln were located between 2 and 18 times plus eight days of RAPT tracking (Table 2). The fewer number of manual tracking locations at Lime Kiln resulted from effort on the RAPT system and tracking species such as lingcod and kelp greenling which were often not detected.

Table 1. Tagged specimen data.

fish #	site	date	floy tag	length (cm)	sex	time caught	time released	pinger code	freq	species
1	Pile Point	03-Aug-02	85	32	f	1645	1800	4-5-6	78	*S. caurinus*
2	Pile Point	04-Aug-02	86	29	m	1030	1059	2-4-9	70	*S. caurinus*
3	Pile Point	04-Aug-02	87	28	f	1130	1202	3-3-5-9	80	*S. caurinus*
4	Pile Point	09-Aug-02	88	34	m	930	1000	3-5-8	71	*S. caurinus*
5	Pile Point	10-Aug-02	89	35	f	1530	1548	2-7-7	79	*S. caurinus*
6	Pile Point	10-Aug-02	91	34	f	1550	1614	3-3-4-4	81	*S. caurinus*
7	Pile Point	20-Aug-02	93	31	f	1905	1918	3-4-3-6	82	*S. caurinus*
9	Lime Kiln	25-Sep-02	94	32	m	1006	1028	8536B	66	*S. caurinus*
10	Lime Kiln	30-Sep-02	95	29	f	1402	1423	8538B	72	*S. caurinus*
11	Lime Kiln	30-Sep-02	96	36	f	1449	1503	8539B	75	*S. caurinus*
12	Lime Kiln	24-Oct-02	98	30	m	1520	1600	8537B	69	*S. caurinus*
13	Lime Kiln	24-Oct-02	83	27	f	1457	1517	8540B	78	*S. caurinus*
14	Lime Kiln	28-Oct-02	82	28	f	1137	1157	8541B	81	*S. caurinus*
15	Lime Kiln	28-Oct-02	81	33	m	1337	1355	8542B	84	*H. decagrammus*
16	Lime Kiln	28-Oct-02	80	33	f?	1427	1450	8535B	63	*H. hemilepidotus*
17	Lime Kiln	24-Oct-02	99	88	f	1615	1645	8-8	73	*O. elongatus*
18	Lime Kiln	01-Sep-01	NA	51	m	NA	NA	6-6	75	*O. elongatus*

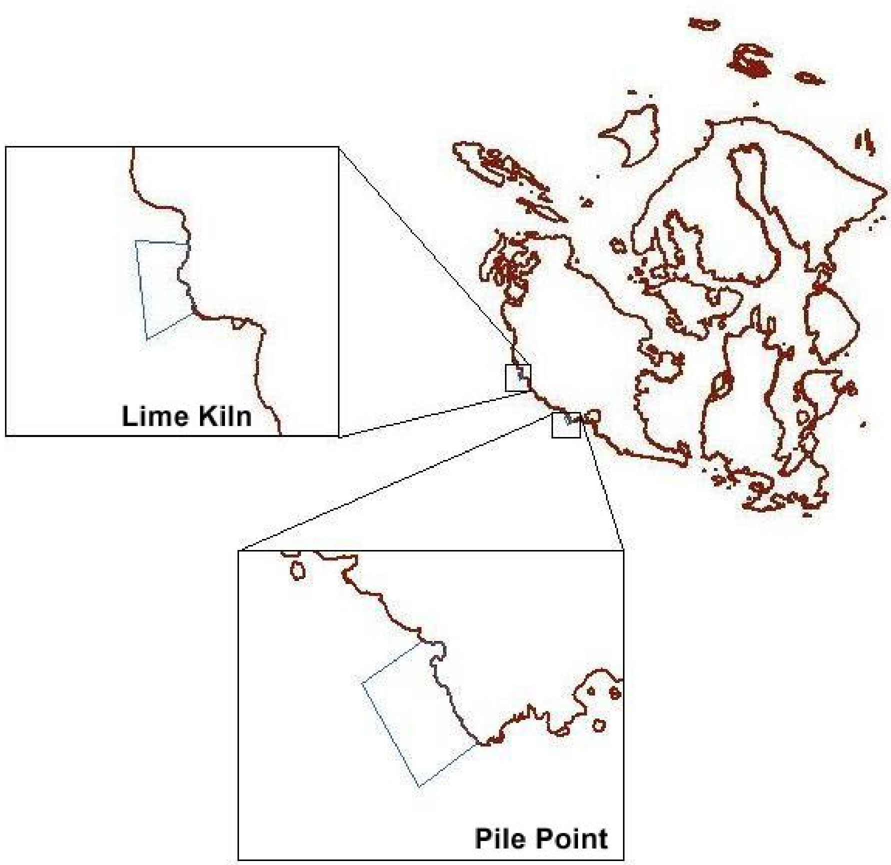

Figure 1. Shoreline at Lime Kiln and Pile Point study sites on the west side of San Juan Island. The BRZ boundaries are the blue boxes extending offshore.

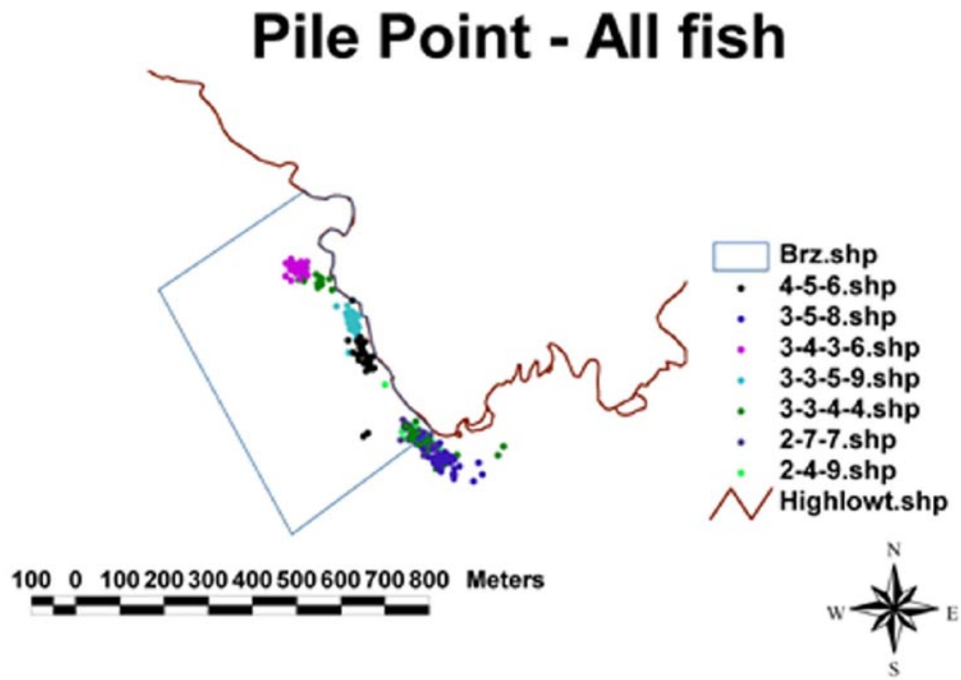

Figure 2. All manual tracking locations of fish at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

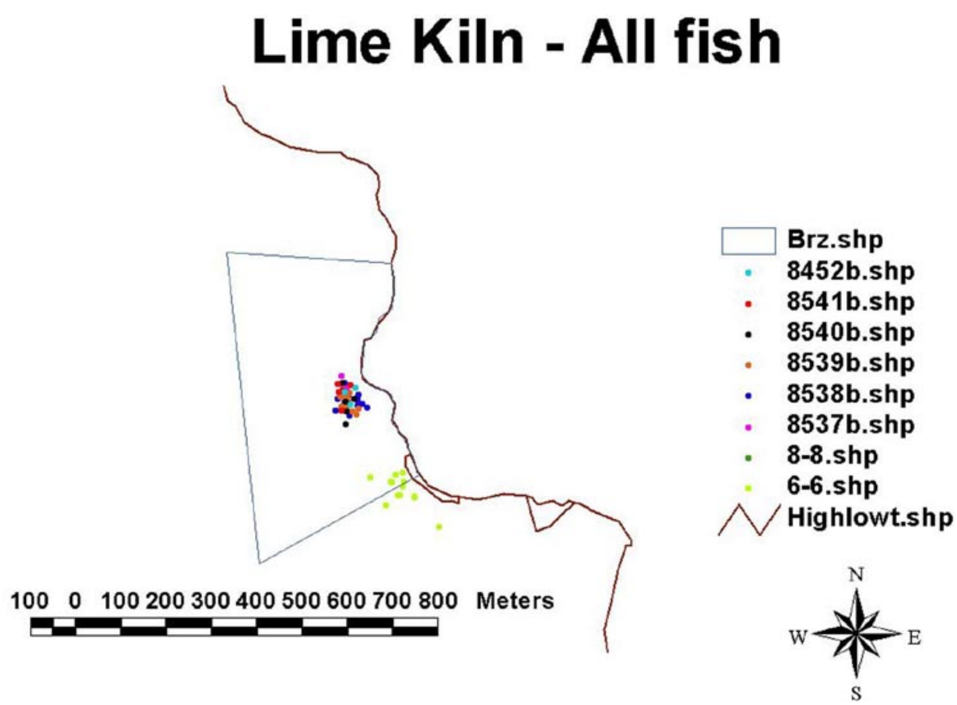

Figure 3. All manual tracking locations of fish at Lime Kiln BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

Table 2. Summary of localization effort.

tag ID	species	sex	length	date tagged	date last detected	# of positions	tracking days	difference	due to...
4-5-6	*S. caurinus*	f	32	03-Aug-02	10-Oct-02	38	46	8	dead battery
2-4-9	*S. caurinus*	m	29	04-Aug-02	21-Oct-02	44	47	3	dead battery
3-3-5-9	*S. caurinus*	f	28	04-Aug-02	28-Oct-02	45	46	1	dead battery
3-5-8	*S. caurinus*	m	34	09-Aug-02	26-Oct-02	43	46	3	dead battery, and high current
2-7-7	*S. caurinus*	f	35	10-Aug-02	28-Oct-02	46	47	1	dead battery
3-3-4-4	*S. caurinus*	f	34	10-Aug-02	28-Oct-02	45	47	2	dead battery, and moved
3-4-3-6	*S. caurinus*	f	31	20-Aug-02	28-Oct-02	40	41	1	dead battery
8536B	*S. caurinus*	m	32	25-Sep-02	26-Nov-02	18+RAPT	18	0	
8538B	*S. caurinus*	f	29	30-Sep-02	26-Nov-02	15+RAPT	15	0	
8539B	*S. caurinus*	f	36	30-Sep-02	26-Nov-02	15+RAPT	15	0	
8537B	*S. caurinus*	m	30	24-Oct-02	26-Nov-02	5 +RAPT	5	0	
8540B	*S. caurinus*	f	27	24-Oct-02	26-Nov-02	5 +RAPT	5	0	
8541B	*S. caurinus*	f	28	28-Oct-02	26-Nov-02	5 +RAPT	5	0	
8542B	*H. decagrammus*	m	33	28-Oct-02	26-Nov-02	3 +RAPT	5	2	no signal detected, moved?
8535B	*H. hemilepidotus*	f	33	28-Oct-02	26-Nov-02	5 +RAPT	5	0	
8-8	*O. elongatus*	f	88	24-Oct-02	02-Dec-02	2 +RAPT	5	3	no signal detected, moved?
6-6	*O. elongatus*	m	51	01-Sep-01	02-Dec-02	13	17	4	no signal detected, moved?

The fish with tag 4-5-6, a 32cm female copper rockfish was not observed outside of the BRZ boundary (Figure 4). The fish with tag 3-5-8, a 34cm male copper rockfish had a home range that would fit inside the BRZ, but it still moved outside of the BRZ boundary (Figure 5). The fish with tag 3-4-3-6, a 31cm female copper rockfish was not observed outside of the BRZ boundary (Figure 6). The fish with tag 3-3-5-9, a 28cm female copper rockfish was not observed outside of the BRZ boundary (Figure 7). The fish with tag 3-3-4-4, a 34cm female copper rockfish had a home range that would fit inside the BRZ, but it still moved outside of the BRZ boundary (Figure 8). The fish with tag 2-7-7, a 35cm female copper rockfish had a home range that would fit inside the BRZ, but it still moved outside of the BRZ boundary (Figure 9). The fish with tag 2-4-9, a 29cm male copper rockfish had a home range that would fit inside the BRZ, but it still moved outside of the BRZ boundary (Figure 10). The fish with tag 8536B, a 32cm male copper rockfish was not observed outside of the BRZ boundary (Figure 11). The fish with tag 8538B, a 29cm female copper rockfish was not observed outside of the BRZ boundary (Figure 12). The fish with tag 8539B, a 36cm female copper rockfish was not observed outside of the BRZ boundary (Figure 13). The fish with tag 8537B, a 30cm male copper rockfish was not observed outside of the BRZ boundary (Figure 14). The fish with tag 8540B, a 27cm female copper rockfish was not observed outside of the BRZ boundary (Figure 15). The fish with tag 8541B, a 28cm female copper rockfish was not observed outside of the BRZ boundary (Figure 16). The fish with tag 8542B, a 33cm male greenling was not observed outside the BRZ boundary (Figure 17), however, it was not detected several times and most likely did move outside the BRZ. The fish with tag 8535, a 33cm red Irish lord was not observed outside of the BRZ boundary (Figure 18). The fish with tag 8-8, a 88cm female lingcod was not observed outside the BRZ boundary (Figure 19), however, it was not detected several times and most likely did move outside the BRZ. The fish with tag 6-6, a 51cm male lingcod had a home range that would fit inside the BRZ, but it still moved outside of the BRZ boundary (Figure 20) and was also not detected several times.

Mobile array

Dr. Ron O'Dor of Dalhousie University loaned a $50,000 RAPT system to the program. This system was deployed and collecting data from 3PM on October 22nd, 2002 until 8AM on October 30th, 2002. The buoy geometry was not an ideal equilateral triangle because of the mooring placement dictated by the study site environment. The bathymetry dropped off quickly near shore and forced the two seaward buoys to be relatively close to shore (Figure 21). However, this geometry did not appear to affect the functioning of the RAPT, other than decreasing the size of the high locationaccuracy-area inside the triangle. The distances between buoys were measured acoustically and determined to be 215m between Buoy 1061 and Buoy 1063, 169m between Buoy 1061 and Buoy 1064, and 64m between Buoy 1063 and Buoy 1064.

Continuous monitoring with the RAPT system showed that copper rockfish did not appear to move out of the home ranges identified through manual tracking. Lingcod and kelp greenling had frequent periods during which they could not be located, similar to the results of manual tracking (Table 2). In addition, the spread of the RAPT localizations for the two *Hexagrammids* was greater than for copper rockfish. The red Irish lord had a pattern similar to the copper rockfish.

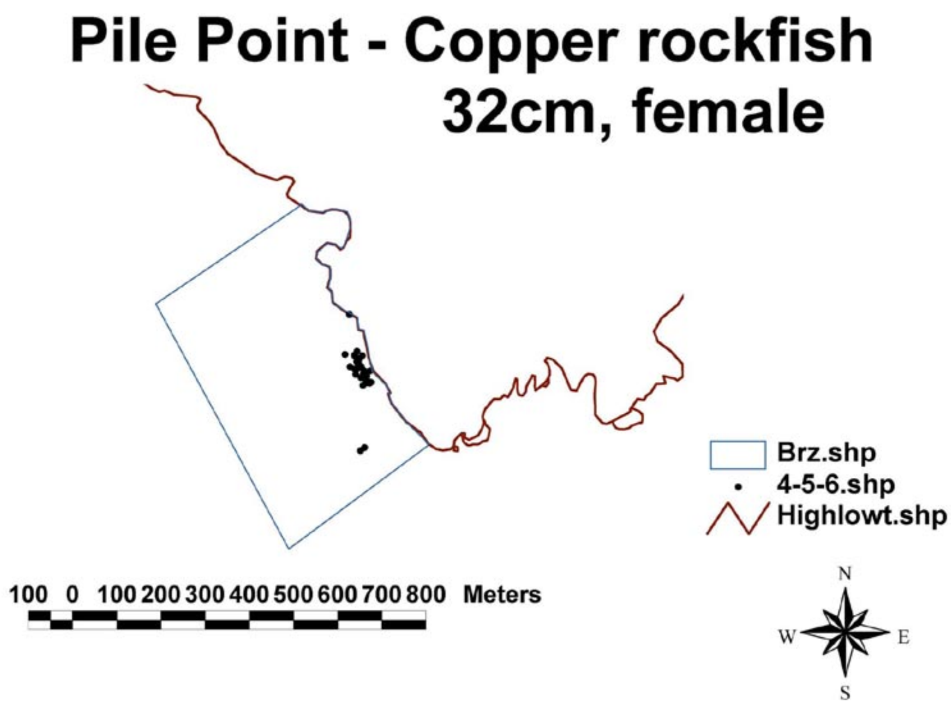

Figure 4. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

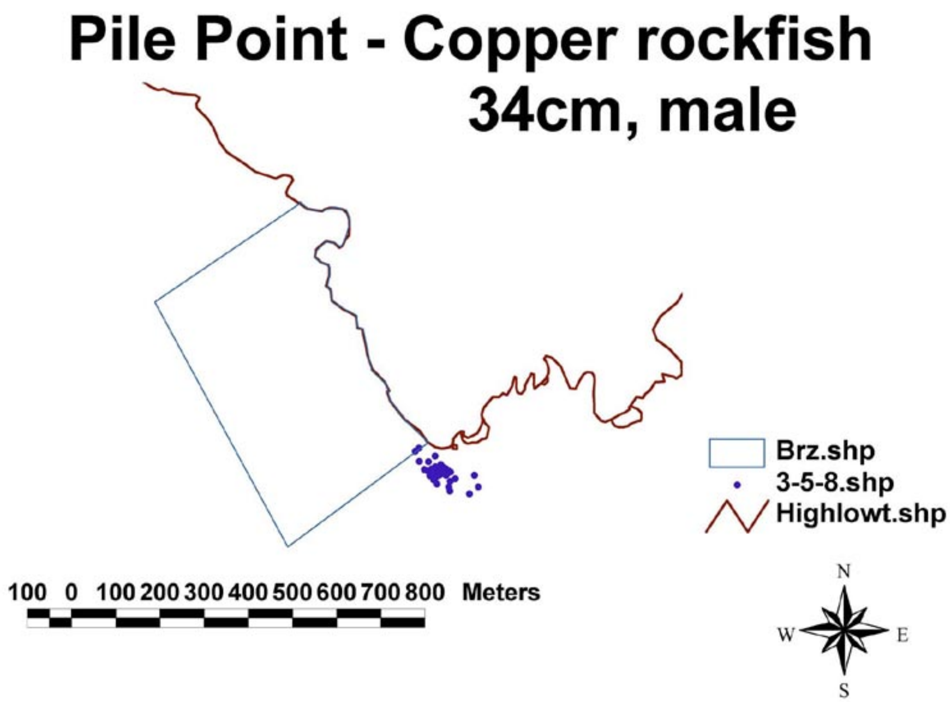

Figure 5. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

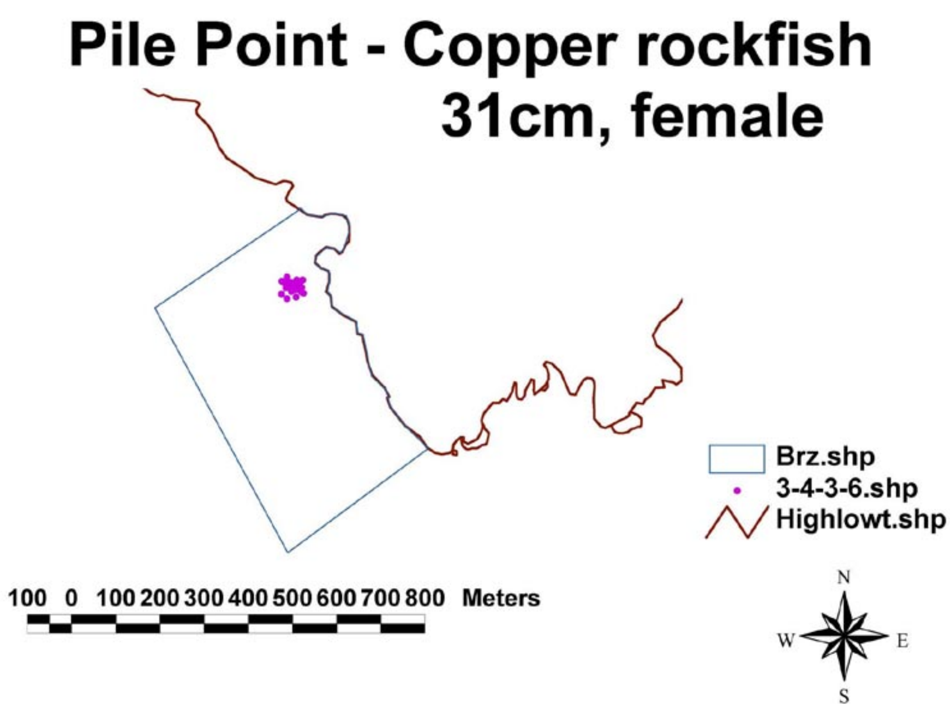

Figure 6. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

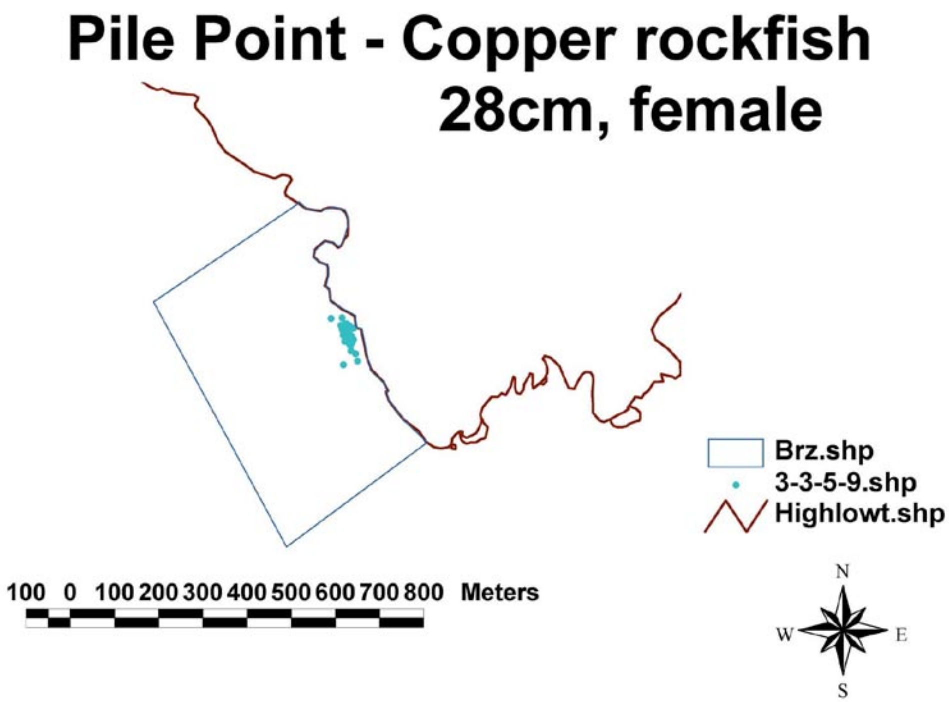

Figure 7. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

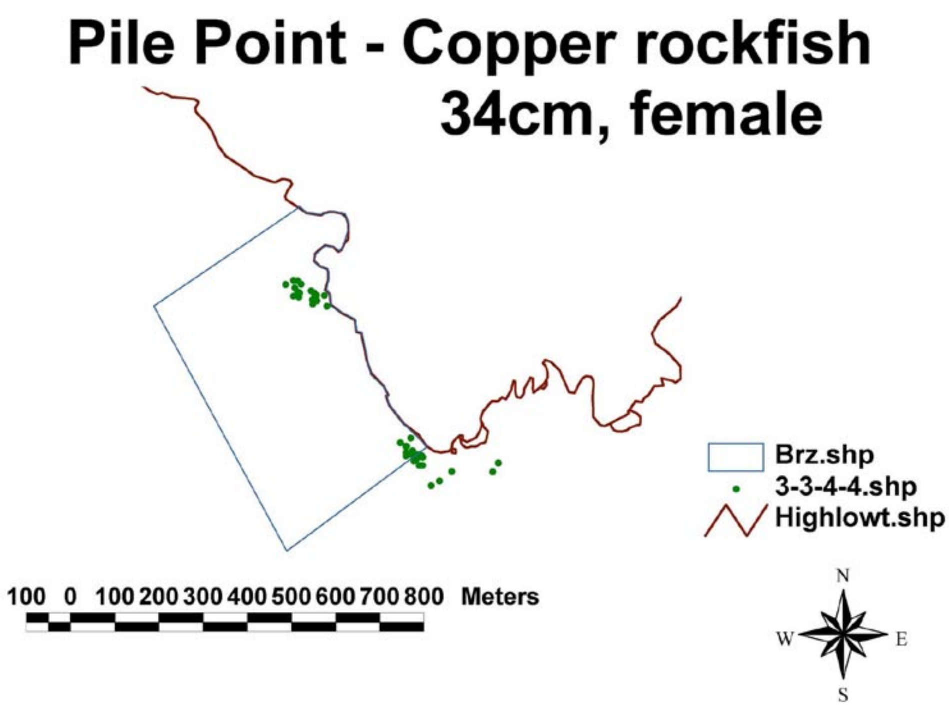

Figure 8. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

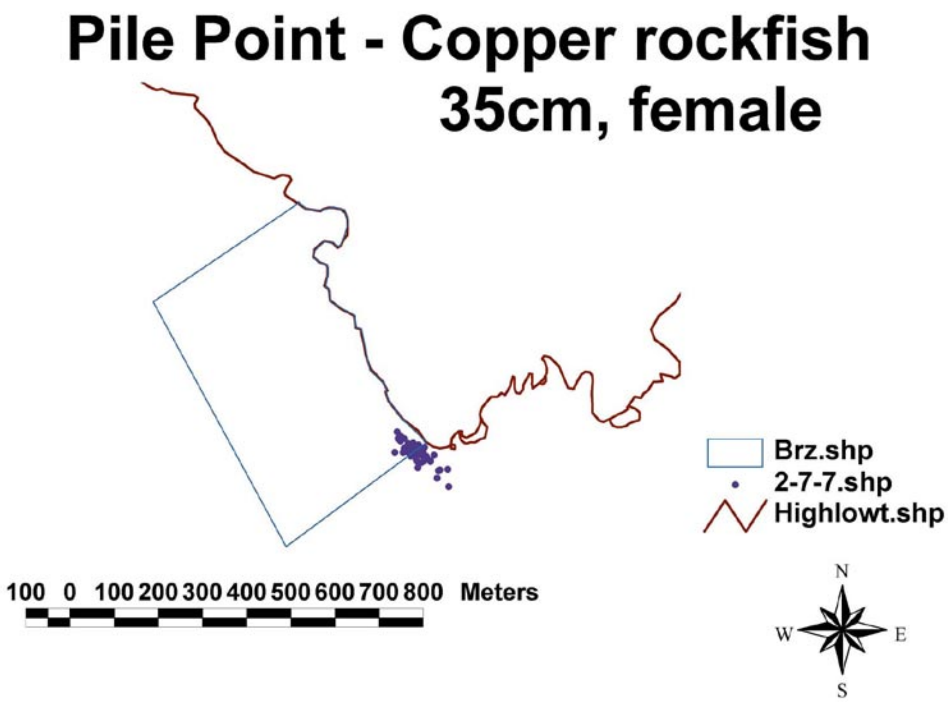

Figure 9. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

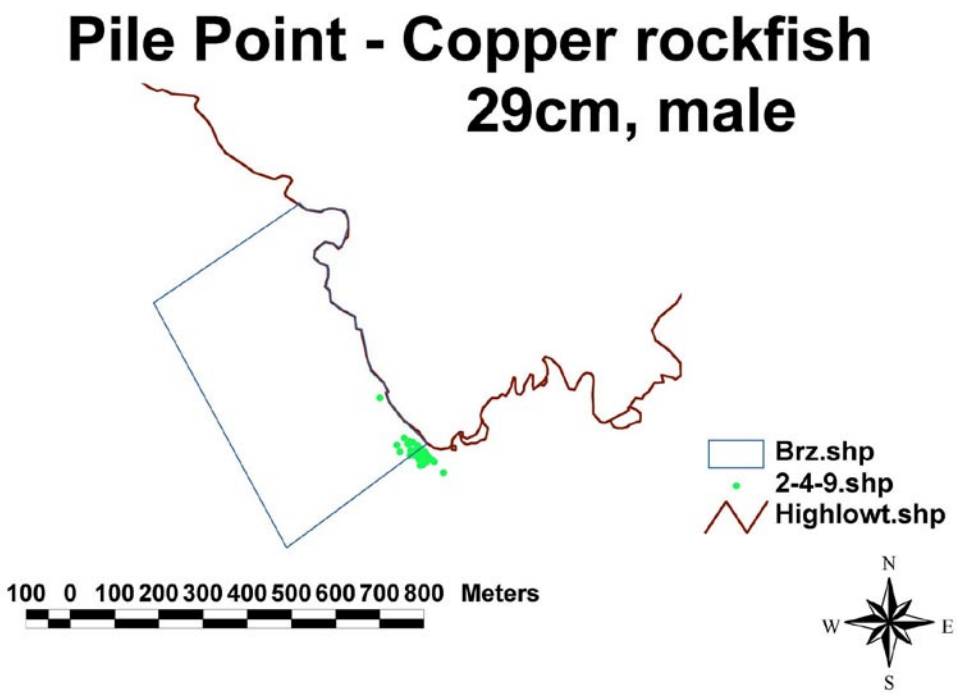

Figure 10. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

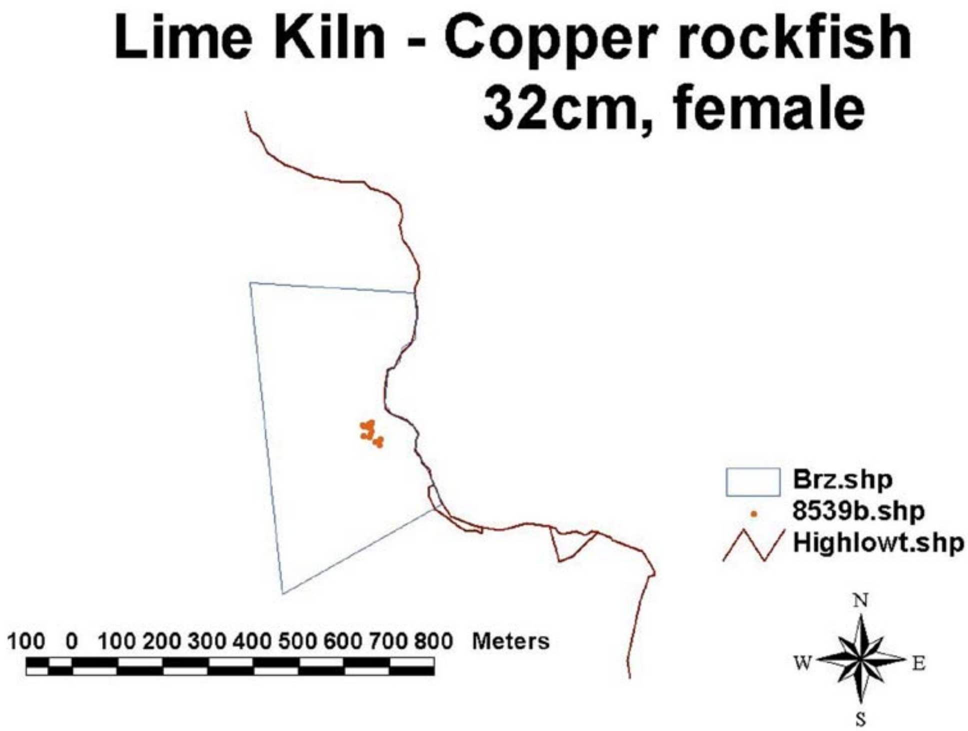

Figure 11. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

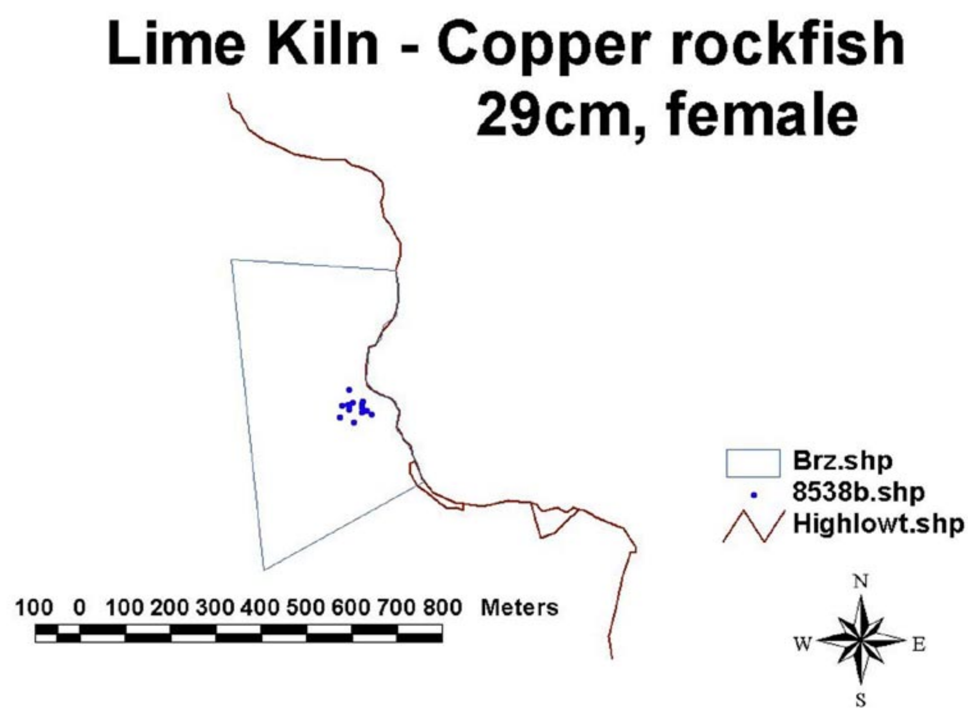

Figure 12. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

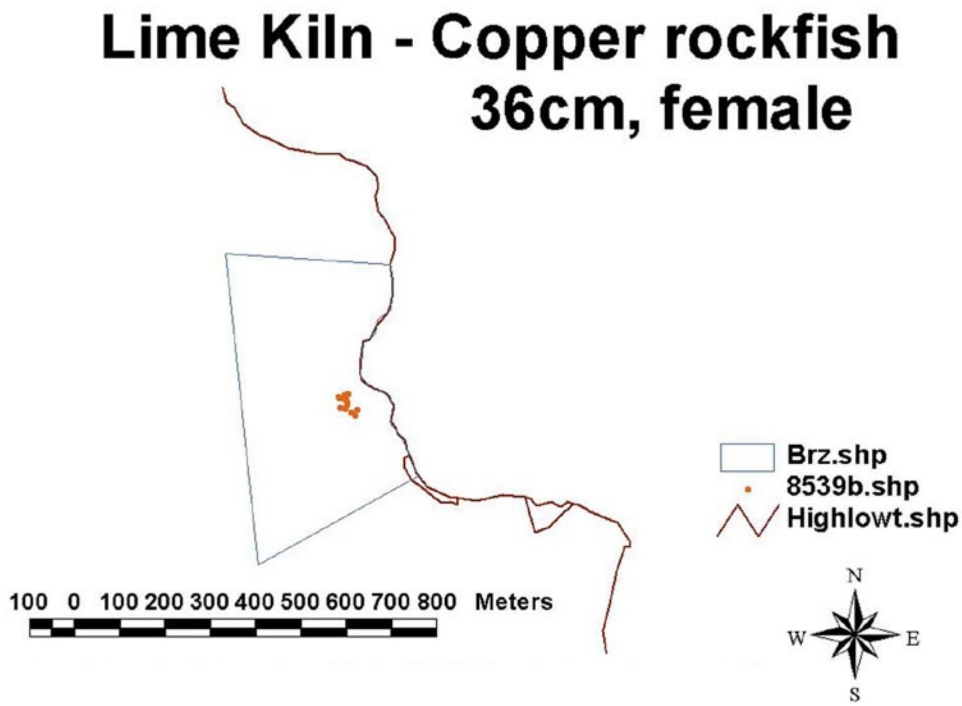

Figure 13. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

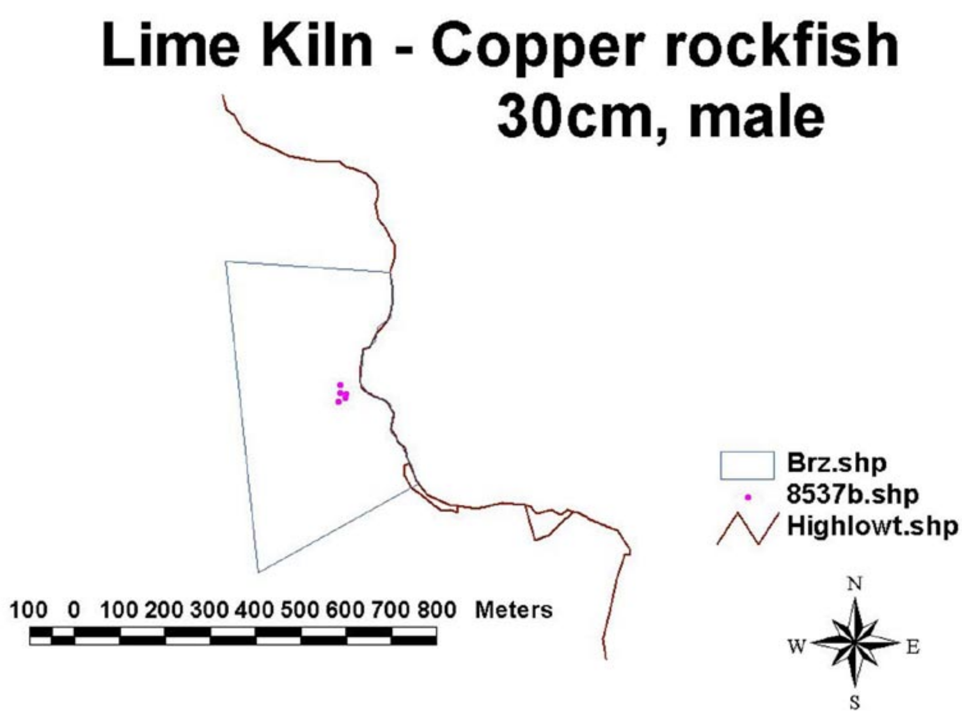

Figure 14. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

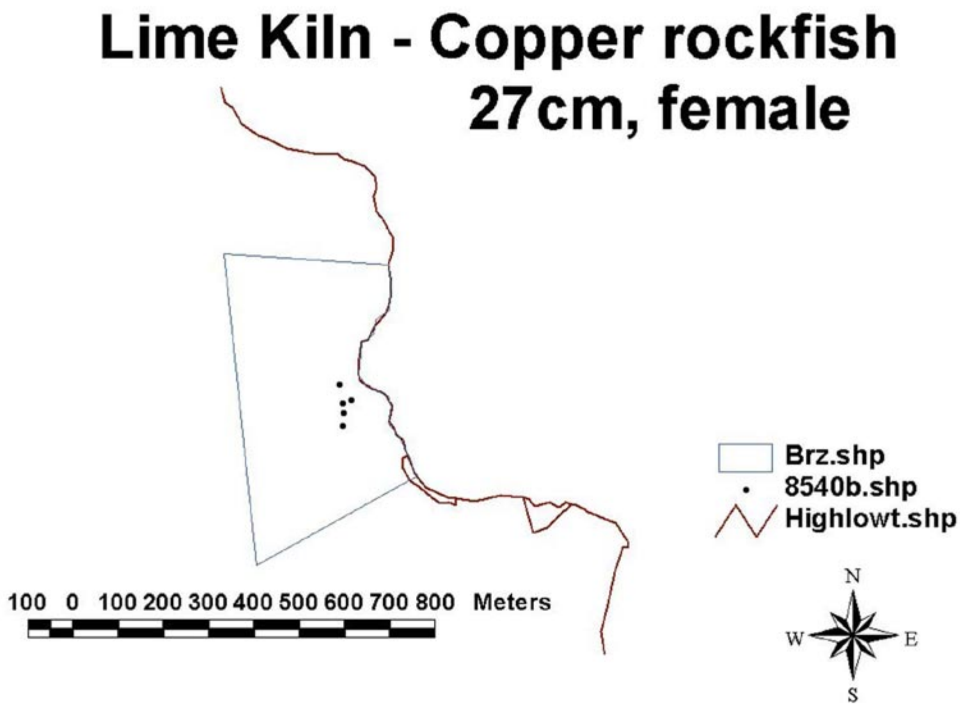

Figure 15. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

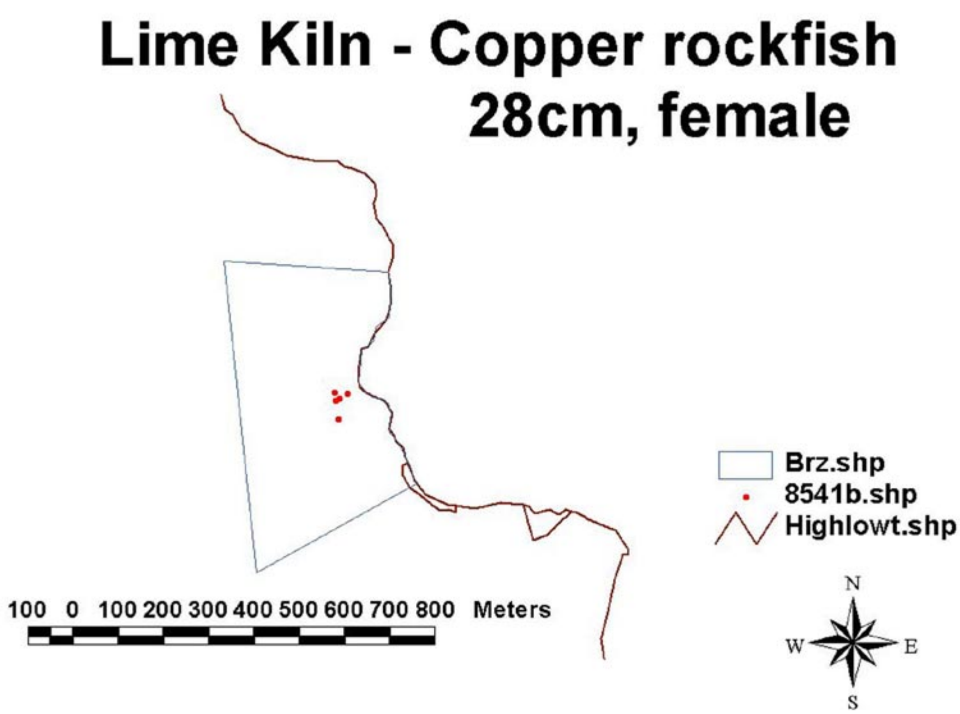

Figure 16. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

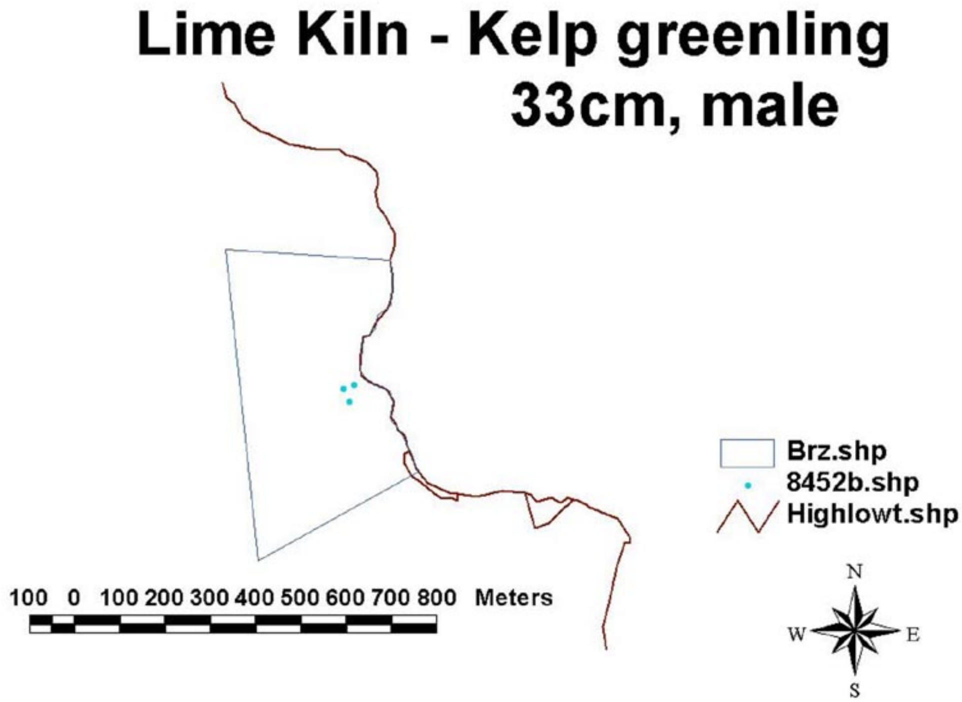

Figure 17. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

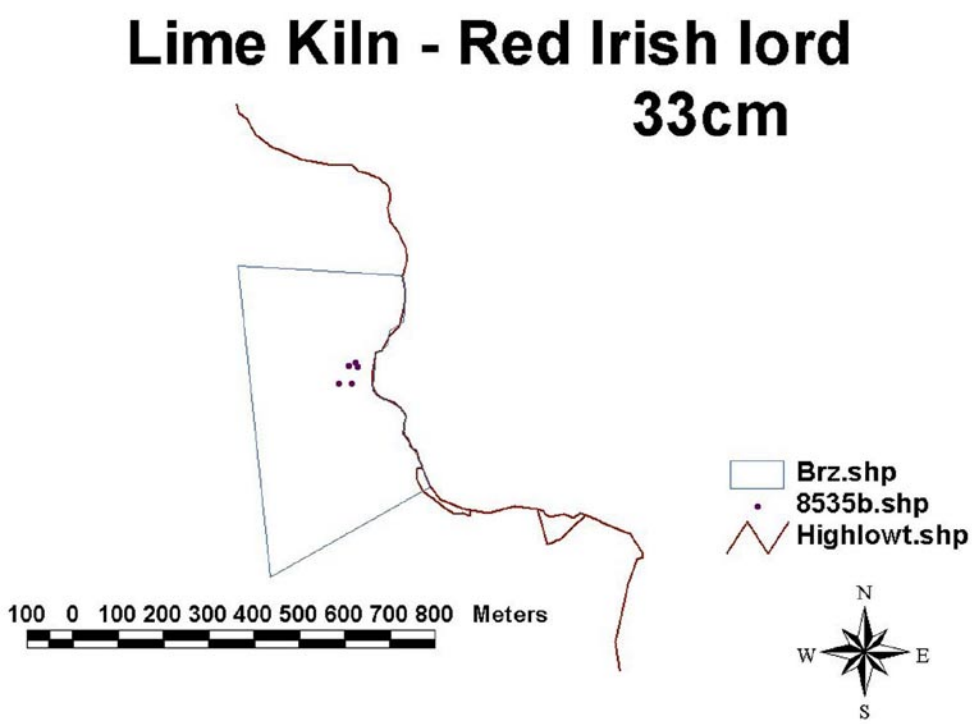

Figure 18. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

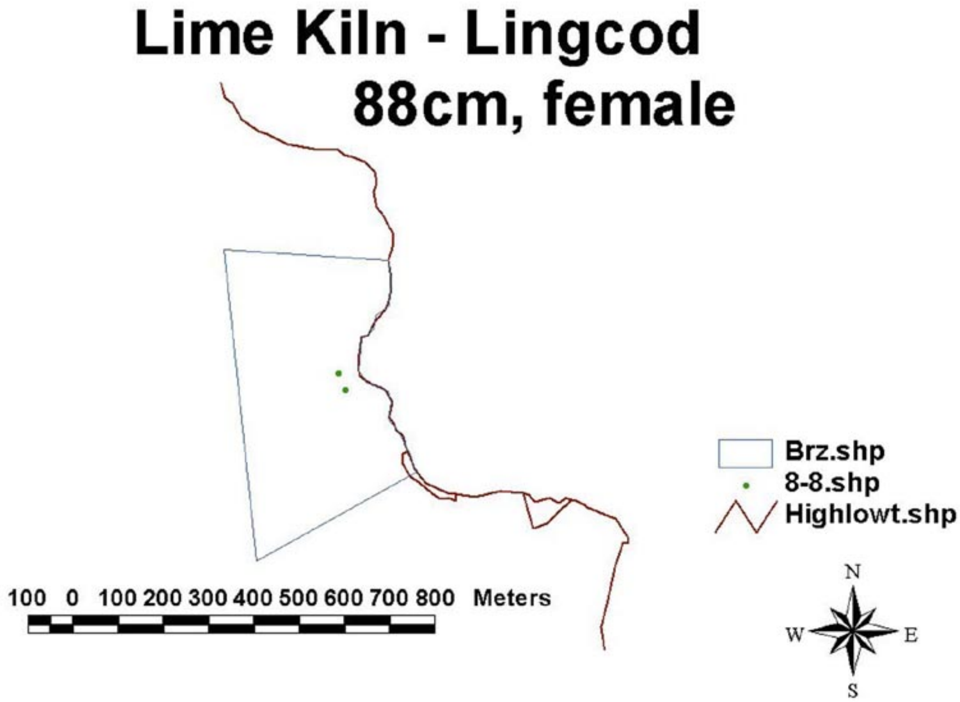

Figure 19. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines. High tide and low tide shoreline denoted by thicker, irregular lines.

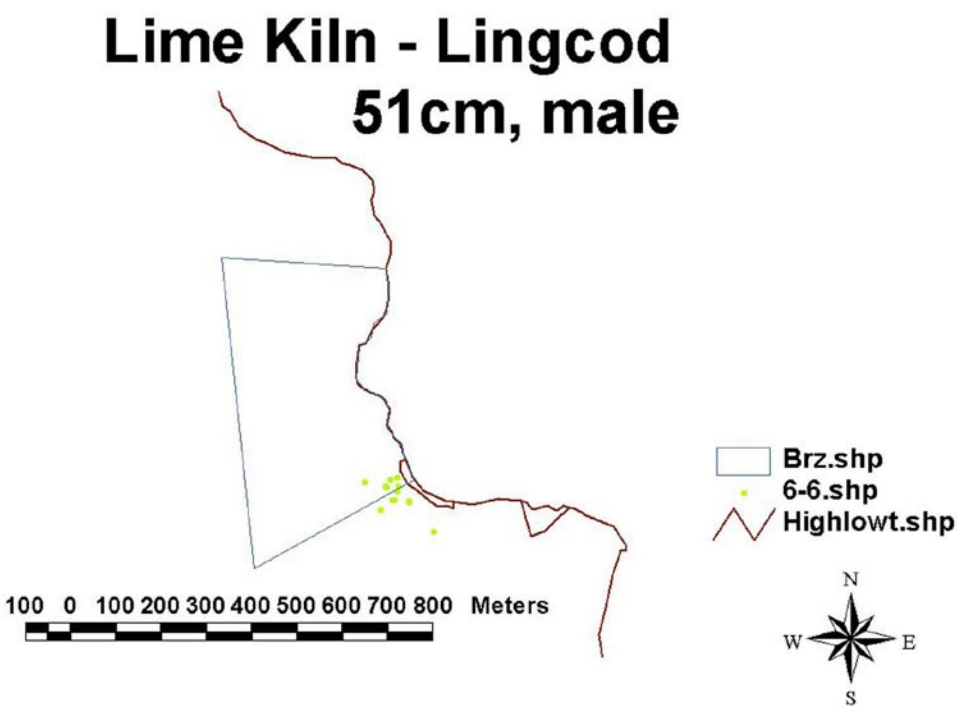

Figure 20. Tracking locations at Pile Point BRZ. BRZ boundary denoted by narrow, straight lines.High tide and low tide shoreline denoted by thicker, irregular lines.

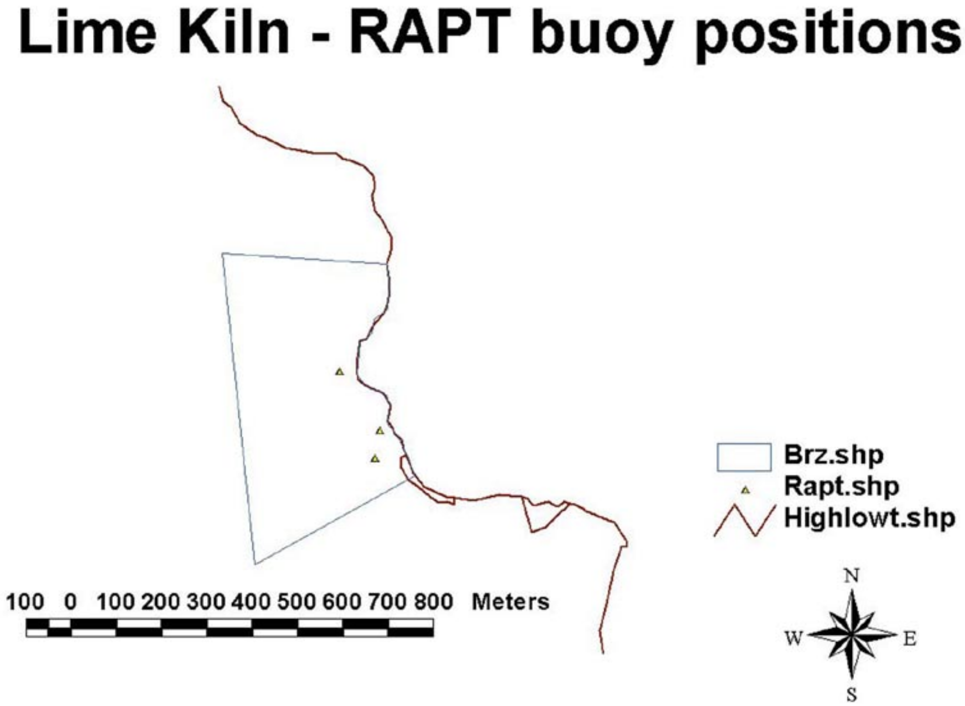

Figure 21. RAPT sono-buoy geometry at Lime Kiln BRZ. Distances between buoys are 215m, 169m and 64m.

Discussion

Manual tracking

The BRZs appear large enough to contain copper rockfish home ranges. Although four of 13 copper rockfish in this study did move outside the BRZ boundaries, in all four cases they were originally captured from just inside the BRZ. The four that moved outside had similar home ranges to those that stayed inside (except for 3-3-4-4). If they had been captured from the center of the BRZ, they probably would not have crossed outside the BRZ boundaries.

Copper rockfish 3-3-4-4 displayed two shifts in home range. 3-3-4-4 was tagged near the tip of Pile Point, moved 200m east and then back to the original location, and then moved 500m northwest and stayed there until the tag batteries died. It is interesting to note that another large female, 35cm 2-7-7, moved very little. In addition, the other females at Pile Point, 32cm 4-5-6, 28cm 3-3-5-9, and 31cm 3-4-3-6 did not make movements like 3-3-4-4. Variation exists in the population.

The BRZs seem too small to encompass the home ranges of lingcod and kelp greenling. The points mapped by manual tracking did lie inside the BRZ, but half of the tracking days spent looking for these fish resulted in no signal being detected. Presumably, these fish moved well outside the BRZ and beyond the 300m detection range of the manual tracking gear used in this study. Perhaps other fishery management techniques, such as seasonal openings, slot size limits and bag limits are more appropriate for these species.

The red Irish lord had a home range size similar to most of the copper rockfish. This shows that reserves designed for target species like copper rockfish may have the additional benefit of protecting non-target species.

It should be noted that this study covers only the autumn season, and home ranges may be different during other seasons. This study needs to be expanded to include data from all 12 months.

Mobile array

The RAPT data, with its substantially increased frequency of localizations compared to manual tracking data, show that tagged copper rockfish did not make quick movements outside the home ranges identified by manual tracking. This is an important finding, because the once per day manual tracking sampling schedule could have been missing diurnal behavior. By combining the knowledge of manual tracking home ranges over a few months with the knowledge from the RAPT data that diurnal movements are contained within the same area, we can say with certainty that the manual tracking home ranges accurately reflect the total area used by these fish during the time period of the study.

In addition, it is reasonable to assume that the copper rockfish home ranges identified at Lime Kiln BRZ are accurate despite fewer manual tracking observations than at Pile Point BRZ. With the exception of 3-3-4-4, the additional manual tracking locations at Pile Point did not add additional information. Just a few manual tracking locations appear to adequately describe the home range of a copper rockfish.

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